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## The Role of Farmers' Risk aversion for Contract Choice in the US Hog Industry

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# The Role of Farmers' Risk aversion for Contract Choice in the US Hog Industry\*

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## Abstract

In this paper we estimate the farmers' side welfare effects of a hypothetical regulatory scenario that would partially eliminate production contracts in the hog industry. Using the Agricultural Resource Management Survey (ARMS) data for 2004, farmers' production costs under different marketing arrangements are estimated and then used to recover their individual risk aversion parameters with the help of a structural expected profit maximization model. The results show that farmers who use production contracts are more risk averse than farmers who use spot markets or marketing contracts. The regulation that forces producers to market their hogs in a riskier marketing channel relative to the channel they themselves selected imposes large welfare losses on the affected farmers.

**KEYWORDS:** spot markets, alternative marketing arrangements, hog industry, risk aversion

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# 1 Introduction

The transactions between producers and packers in the hog industry occur in cash or spot markets or through different types of alternative marketing arrangements (AMAs). Alternative marketing arrangements refer to all possible alternatives to the spot market and include arrangements such as procurement or marketing contracts, production contracts, packer owned production, etc. The issues of farm-level price formation in the hog sector are capturing the attention of regulators and policy makers due to the declining importance of spot markets relative to the AMAs. A recently completed survey of hog producers and packers (Vukina et al. 2007) shows that in the 2004/2005 period only 24% of the market hogs were transacted on the cash/spot markets. As a comparison, in 1999, this share was 36% (Grimes, Plain, and Meyer, 2003).

The increasing reliance on AMAs by pork packers at the expense of reduced share of cash/spot markets is the subject of heated theoretical and policy controversies. One line of thought (espoused in the beef industry studies) is that, because AMAs supplies provide a substantial portion of packers' needs, the demand for spot market animals declines, and assuming that this decrease in demand is not accompanied by an adequate decrease in supply, the cash price will be negatively affected (Schroeder et al., 1993). Another line of thought claims that price effect of AMAs is neutral, because, for example, if 10% of the demand for live animals is removed, so is 10% of the supply, and the net effect on the market is zero (USDA-AMS, 1996).

Despite many theoretically and empirically unresolved issues, the pressure on both federal and states legislatures to regulate all or some forms of packer ownership of livestock, including production contracts, is mounting. The concerns about the effects of packer ownership supplies on cattle prices culminated in a legislation proposed as part of the 2002 Farm Bill (subsequently omitted) to ban most packer ownership of cattle. As recently as Fall 2007, the Senate Agriculture Committee passed an amendment to its version of the 2007 Farm Bill that would prohibit packers from owning livestock for more than 14 days before slaughter. Under the proposed amendment to the Packers and Stockyards Act, packers could not, "own or feed livestock directly, through a subsidiary, or through an arrangement that gives the packer operational, managerial, or supervisory control over the livestock, or over the farming operation that produces the livestock."<sup>1</sup> Such language was not included in the House version of the 2007 Farm Bill.

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<sup>1</sup>The full text of the "en bloc amendment" can be found on the Senate Agriculture Committee Web site, <http://www.agriculture.senate.gov/>.

The objective of this article is to estimate the farmers' side welfare effects of a hypothetical regulatory scenario that would reduce the use of production contracts in the hog industry. The study focuses on the importance of farmers' risk aversion on the contract choice. We focus on two objectives. First, in a structural econometrics framework we measure the risk aversion coefficients for two distinct group of farmers: those that chose cash or marketing contracts to market their hogs, and those that chose production contracts with an integrator or a packer. Second, we measure the welfare loss solely attributable to forcing producers to abandon the marketing arrangement that, based on their risk aversion preferences, they chose as their most preferred type and switch to a less preferred choice.

In this regard this research contributes to the literature on testing the trade-off between risk and incentives. On one hand, the transaction cost literature (e.g., Allen and Lueck, 1992) claims that risk is unimportant for contract choice. On the other hand, Akerberg and Botticini (2002) showed that if one controls for the endogenous matching between principals and agents, the agent's risk aversion appears to significantly influence the contract choice. Another example is found in Pennings and Smidts (2000) who also determined that the degree of risk aversion is an important factor in explaining owner-managers' choice between relatively safe fixed-price contracts versus spot market transactions.

Our approach is based on a structural model, where a risk averse farmer maximizes his expected profit under price uncertainty by choosing the volume of output (the number of hogs produced). The data on individual farmer's marketing choices, production decisions, and socioeconomic characteristics come from the Agricultural Resource Management Survey (ARMS) for 2004. We estimate the primitives of the structural model (utility and cost functions parameters) and perform an illustrative welfare simulation where a complete ban on the production contracts is imposed in only one state. To avoid dealing with the general equilibrium type of problems related to the establishment of the new post-regulation equilibrium prices, we choose the state of South Dakota. When it comes to the use of production contracts in the hog industry, South Dakota is a small state so the effect of this hypothetical regulation on the entire industry is expected to be negligible and only affect those farmers who reside in that state.

Our results show that farmers who self-select themselves into production contracts are generally more risk averse than farmers who decided to market their hogs via the cash (spot) market or marketing contracts. Since this marketing arrangement carries higher risk, in order to reduce their risk exposure, risk-averse farmers respond by reducing output. The reduction in output due

to forcing the farmers out of their preferred marketing choice creates a substantial welfare loss.

## 2 Industry Description

Historically, hogs were raised in farrow-to-finish operations on small diversified farms. Starting in the 1950s the process of specialization into feed grain production and livestock farms has gradually begun. Nowadays hogs are commonly produced by specialized operations that use separate production facilities for each phase of production. The production of hogs has three phases: farrow-to-wean, wean-to-feeder, and feeder-to-finish. During the farrow-to-wean phase, hog producers breed sows for the production of nursing pigs. These pigs are weaned at 2-3 weeks of age (8-12 pounds). Weaned pigs enter the wean-to-feeder production stage where they are fed for approximately 6 weeks or until they weigh 40-55 pounds. In the feeder-to-finish segment, feeder pigs are fed for approximately 16 weeks until they reach a market weight of 250 to 290 pounds. In addition to single stage operations, some operations combine multiple stages of production. For example, farrow-to-finish operations combine all three stages, whereas farrow-to-feeder or wean-to-finish operations cover only two. After they reach the market weight, finished hogs are shipped to packing plants. Hog carcasses are inspected for wholesomeness by United States Department of Agriculture/Food Safety and Inspection Service (USDA/FSIS) or by a state inspection system. Unlike beef, pork is rarely quality graded by USDA/Agricultural Marketing Service (USDA/AMS). Instead, packers rely on other measures of quality, such as lean percentage, back fat, and loin eye depth (for details see Vukina, 2008).

There are many different types of marketing arrangements used for sales of live pigs and hogs. The type of marketing arrangement used, among other things, also depends on the type of animals marketed. In this paper, we are exclusively concerned with the alternative marketing arrangements used by farmers to sell their market (finished) hogs. There are three main channels that farmers have access to: cash or spot market, marketing contracts, and production contracts. On the other side of each transaction is either a packer or a non-packing integrator.

When purchasing finished hogs on cash or spot markets, pork packers predominantly use direct or negotiated trades (Vukina and Zheng, 2007). These methods are predominantly used in the Midwest. Farmers relying on spot markets assume the entire price risk which can be substantial. In addition, these producers typically face the risk of inadequate market access that manifests

itself in having difficulty finding buyers, or more likely in scheduling deliveries consistent with the timing of their production systems.

Marketing contracts are verbal or written agreements between a contractor and a producer to transfer the ownership of pigs at some time in the future. A marketing contract sets a price (or a pricing mechanism) and an outlet for pigs before they are ready to be transferred. Contracts often specify product quantities, the range of acceptable quality measures, and delivery schedules. Most management decisions remain with growers because they retain the ownership of the animals during the growing stage. The pricing mechanism could somewhat limit the producer's exposure to price risk, but more importantly, a marketing contract provides the producer with a secure outlet for hogs.<sup>2</sup>

A production contract is an agreement between an integrator or a packer (principal) and a grower (agent) that obliges the grower to tend for principal's animals according to specific production practices in return for monetary compensation. The most frequently observed contracts in the pork industry are single production-stage contracts such as finishing contracts. Some integrators and packers offer contracts that combine several production stages under one contract. These are known as farrow-to-finish contracts or wean-to-finish contracts. All production contracts have two main components: one is the division of responsibility for providing inputs, and the other is the method used to determine grower compensation. Growers provide land, housing facilities, utilities (electricity and water), and labor and are also responsible for manure management and disposal of dead animals. The principal retains the ownership of animals throughout the production process and provides feed, medication, and services of field personnel. She is also the residual claimant on realized profits.

A hog farmer's risk exposure in a production contract is substantially lower than in either a marketing contract or on the spot market. The majority of finishing contracts are settled by some form of a fixed performance standard where growers are competing against a predetermined constant technological standard such as the feed conversion ratio. The payment takes the form of a variable piece rate where the variation in individual piece rates depends on how efficiently the grower used the principal-supplied inputs. The payment scheme never includes the prices of inputs or outputs making the contract producer completely insulated from market prices volatilities.

The primary motives for packers to offer production and marketing con-

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<sup>2</sup>Since there is no way to quantify market access risk from the available data, in our modeling and estimation approach, this type of risk is ignored and marketing contracts and cash/spot sales are treated as one category.

tracts include quantity and quality assurances. Meat packing exhibits substantial economies of scale in processing and waste management. Therefore, large packing plants face high fixed costs and strive to achieve high capacity utilization. In an attempt to reduce the risk of hog supply shortages, packers have strong incentives to attenuate supply variation by forward scheduling hogs for slaughter. A related factor is a desire to narrow quality standards for incoming hogs. This is dictated both by consumer demand and by a highly automated production process.

### 3 A Simple Model

We model the two-stage decision process of a risk-averse hog farmer who, in the first stage, decides which marketing arrangement to use and then in the second stage, given the chosen marketing arrangement  $d$ , needs to decide on how many hogs  $q_d$  to produce in a given time period. Using backward induction, we first solve for the farmer's second stage production decision and then, conditional on the second stage optimal production decision, pick the channel that yields greater expected utility.

Strictly speaking, the decision on how many hogs to produce in a given period may suffer from the lumpiness problem and is constrained from above by the available production capacity. An independent farmer has the most freedom since he can choose to leave the entire or part of the facility empty if the market conditions are unfavorable. A farmer with a marketing contract is more constrained in the sense that he could be obliged by the contract to produce so many hogs per time period. Finally, a farmer with a production contract essentially made the production decision by choosing the production capacity when signing the first contract. Production contracts usually require standardized production units (moduli) of minimum efficient size and the contract grower only needs to decide how many of those moduli he wants to invest in. Once the facility is constructed, in each subsequent contract the decision on how many hogs to produce in a given period (say a year) takes the form of delaying or expediting the receipt of a new batch of feeder pigs or by keeping some of the production units idle. For analytical tractability reasons, we treat the quantity decision variable as continuous and non-truncated.

The model itself is based on several rather standard and innocuous assumptions. First, we assume that the farmer's utility function exhibits constant absolute risk-aversion (CARA) preference structure

$$U(R(q_d), C(q_d), \gamma) = 1 - \frac{1}{\gamma} \exp[-\gamma(R(q_d) - C(q_d))] \quad (1)$$

where  $\gamma > 0$  is the risk aversion parameter. Second, at the time farmers make decisions on the number of hogs to produce  $q_d$ , the price  $p_d$  and hence the revenue  $R_d = p_d q_d$  is uncertain and assumed normally distributed. Finally, following Porter (1983), we assume that the production costs can be adequately represented by the reduced-form specification  $C(q_d) = \alpha_{0d} + \alpha_{1d}q_d + \frac{\alpha_{2d}}{2}(q_d)^2 + \varepsilon_d$  where  $\varepsilon_d$  is an unobserved (to the econometrician) cost component which follows normal distribution with mean 0 and  $\sigma_d^2$  variance.<sup>3</sup> Using these assumptions, a farmer's expected utility can be expressed as an increasing concave function of the mean-variance criterion (which corresponds to the certainty equivalent value of revenue) and his maximization problem can be written equivalently as

$$\begin{aligned} \max_{q_d} W(R_d, q_d) &= E(R_d) - \frac{\gamma}{2} \text{Var}(R_d) - C(q_d) \\ &= E(p_d) q_d - \frac{\gamma}{2} \text{Var}(p_d) (q_d)^2 - \alpha_{0d} - \alpha_{1d}q_d - \frac{\alpha_{2d}}{2}(q_d)^2 - \varepsilon_d. \end{aligned} \quad (2)$$

The implied first order condition for this problem is

$$E(p_d) - \gamma \text{Var}(p_d) q_d^* - \alpha_{1d} - \alpha_{2d}q_d^* = 0. \quad (3)$$

The second order sufficient condition is also satisfied for all  $q_d^*$  and therefore  $q_d^*$  is unique.

When choosing to produce at the optimal quantity, a farmer's incurred production cost is given by

$$C(q_d^*) = \alpha_{0d} + \alpha_{1d}q_d^* + \frac{\alpha_{2d}}{2}(q_d^*)^2 + \varepsilon_d \quad (4)$$

and the resulting expected utility becomes

$$W(R_d^*, q_d^*) = E(p_d) q_d^* - \frac{\gamma}{2} \text{Var}(p_d) (q_d^*)^2 - \alpha_{0d} - \alpha_{1d}q_d^* - \frac{\alpha_{2d}}{2}(q_d^*)^2 - \varepsilon_d. \quad (5)$$

Now, back in the first stage, the farmer chooses a cash-marketing arrangement (denoted as  $d = 1$ ) as long as  $W(R_1^*, q_1^*) > W(R_2^*, q_2^*)$ . Otherwise, he chooses a production contract (denoted as  $d = 2$ ).

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<sup>3</sup>Production economists often estimate structural cost functions, specified as functions of factor prices and the level of output, and then derive factor demands using Shepard's lemma. The procedure involves estimating a system of equations, which include both the cost function and the factor demand functions. Using such an approach requires variation in input prices, which is easily met if time series data are used. Since we deal with the cross-sectional data, this approach is unusable since prices for certain inputs (like the wage rates) are the same for all farmers in one region resulting in not enough variation. On the other hand, as pointed out by a referee, prices for other inputs (like the prices of feed) can be imputed from our data, but such imputation leads to too much variation to be believable.

### 3.1 Estimation

In the estimation of this model the statistical inference is based on the assumption that the number of farmers approaches infinity. Therefore, possible farmers heterogeneity needs to be taken into account. This issue can be addressed by modeling farmers' costs to depend on their socioeconomic characteristics. Specifically, let farmers be indexed by  $(i = 1, \dots, N_d)$  where  $N_d$  denotes the number of farmers in the dataset using marketing arrangement  $d$ , and specify  $\alpha_{i1d} = x_i \phi_d$  where  $x_i$  is a vector of variables characterizing the observed heterogeneity of farmer  $i$ .

The purpose of estimation is to recover the model primitives, that is, the farmers' risk aversion and the cost function parameters. To do so, we first derive the probability of farmer  $i$  choosing a cash-marketing arrangement. From the first stage of the model described above, this can be obtained as

$$\begin{aligned} \Pr(d_i = 1) &= \Pr[W(R_{i1}^*, q_{i1}^*) > W(R_{i2}^*, q_{i2}^*)] \\ &= \Pr \left[ \begin{array}{l} \varepsilon_{i2} - \varepsilon_{i1} > E(p_2) q_{i2}^* - \frac{\gamma_i}{2} \text{Var}(p_2) (q_{i2}^*)^2 - \alpha_{02} - \alpha_{i12} q_{i2}^* - \frac{\alpha_{22}}{2} (q_{i2}^*)^2 \\ - (E(p_1) q_{i1}^* - \frac{\gamma_i}{2} \text{Var}(p_1) (q_{i1}^*)^2 - \alpha_{01} - \alpha_{i11} q_{i1}^* - \frac{\alpha_{21}}{2} (q_{i1}^*)^2) \end{array} \right]. \end{aligned} \quad (6)$$

Next, we assume that  $\varepsilon_{i1}$  and  $\varepsilon_{i2}$  are independent and therefore  $\varepsilon_{i2} - \varepsilon_{i1}$  is normal with variance  $\sigma_1^2 + \sigma_2^2$ , leading to<sup>4</sup>

$$\begin{aligned} \Pr(d_i = 1) &= \\ 1 - \Phi &\left[ \frac{\left[ \begin{array}{l} E(p_2) q_{i2}^* - \frac{\gamma_i}{2} \text{Var}(p_2) (q_{i2}^*)^2 - \alpha_{02} - \alpha_{i12} q_{i2}^* - \frac{\alpha_{22}}{2} (q_{i2}^*)^2 \\ - (E(p_1) q_{i1}^* - \frac{\gamma_i}{2} \text{Var}(p_1) (q_{i1}^*)^2 - \alpha_{01} - \alpha_{i11} q_{i1}^* - \frac{\alpha_{21}}{2} (q_{i1}^*)^2) \end{array} \right]}{\sqrt{\sigma_1^2 + \sigma_2^2}} \right] \end{aligned} \quad (7)$$

and  $\Pr(d_i = 2) = 1 - \Pr(d_i = 1)$ .

Hence, given the model primitives (covariates and parameters), the probability of observing a farmer with production cost  $C_i$  that self-selected himself

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<sup>4</sup>Though the independence assumption is strong, it is necessary. This is because for any farmer  $i$ ,  $C_{i1}$  and  $C_{i2}$  are never observed at the same time and, as a result, the covariance of  $\varepsilon_{i1}$  and  $\varepsilon_{i2}$  cannot be identified if  $\varepsilon_{i1}$  and  $\varepsilon_{i2}$  are correlated. See Maddala (1983, Ch. 9) for further discussion of this type of models.

into a cash-marketing arrangement is

$$\begin{aligned} \Pr(d_i = 1, C_i | x_i, \Delta) &= \Pr(d_i = 1 | x_i, \Delta) * \Pr(C_i | x_i, \Delta, d_i = 1) \\ &= \left\{ 1 - \Phi \left[ \frac{E(p_2) q_{i2}^* - \frac{\gamma_i}{2} \text{Var}(p_2) (q_{i2}^*)^2 - \alpha_{02} - \alpha_{i12} q_{i2}^* - \frac{\alpha_{22}}{2} (q_{i2}^*)^2}{\sqrt{\sigma_1^2 + \sigma_2^2}} \right. \right. \\ &\quad \left. \left. - \frac{E(p_1) q_{i1}^* - \frac{\gamma_i}{2} \text{Var}(p_1) (q_{i1}^*)^2 - \alpha_{01} - \alpha_{i11} q_{i1}^* - \frac{\alpha_{21}}{2} (q_{i1}^*)^2}{\sqrt{\sigma_1^2 + \sigma_2^2}} \right] \right\} \\ &\quad \times \phi \left( \frac{C_i - \alpha_{01} - \alpha_{i11} q_{i1}^* - \frac{\alpha_{21}}{2} (q_{i1}^*)^2}{\sqrt{\sigma_1^2}} \right). \end{aligned} \quad (8)$$

where  $\Delta = (\phi_d, \alpha_{0d}, \alpha_{2d}, \sigma_d^2)$ , and the second equality follows from expressions (7) and (4) and the assumption that  $\varepsilon_{i1}$  is normal.

Given the fact that for cash-marketing farmers we only observe  $q_{i1}^*$ , in order to evaluate the resulting likelihood function we need to substitute away  $\gamma_i$  and  $q_{i2}^*$  in (8). This is accomplished by using two relationships, both of which follow directly from the first order condition (3), namely

$$\gamma_i = \frac{E(p_1) - \alpha_{i11} - \alpha_{21} q_{i1}^*}{\text{Var}(p_1) q_{i1}^*} = \frac{E(p_2) - \alpha_{i12} - \alpha_{22} q_{i2}^*}{\text{Var}(p_2) q_{i2}^*} \quad (9)$$

and

$$q_{i2}^* = \frac{E(p_2) - \alpha_{i12}}{\gamma_i \text{Var}(p_2) + \alpha_{22}} = \frac{E(p_2) - \alpha_{i12}}{\left[ \frac{E(p_1) - \alpha_{i11} - \alpha_{21} q_{i1}^*}{\text{Var}(p_1) q_{i1}^*} \right] \text{Var}(p_2) + \alpha_{22}}. \quad (10)$$

By doing this (8) can be rewritten as:

$$\begin{aligned} \Pr(d_i = 1, C_i | x_i, \Delta) &= \\ &\left\{ 1 - \Phi \left[ \frac{\frac{1}{2} \frac{[E(p_2) - \alpha_{i12}]^2}{\left[ \frac{E(p_1) - \alpha_{i11} - \alpha_{21} q_{i1}^*}{\text{Var}(p_1) q_{i1}^*} \right] \text{Var}(p_2) + \alpha_{22}} + \alpha_{01} - \alpha_{02} - \frac{1}{2} [E(p_1) - \alpha_{i11}] q_{i1}^*}{\sqrt{\sigma_1^2 + \sigma_2^2}} \right] \right\} \\ &\quad \times \phi \left( \frac{C_i - \alpha_{01} - \alpha_{i11} q_{i1}^* - \frac{\alpha_{21}}{2} (q_{i1}^*)^2}{\sqrt{\sigma_1^2}} \right). \end{aligned} \quad (11)$$

Similarly, the probability of observing a farmer with the production cost  $C_i$  that self-selected himself into a production contract can be derived as

$$\begin{aligned} \Pr(d_i = 2, C_i | x_i, \Delta) &= \Pr(d_i = 2 | x_i, \Delta) * \Pr(C_i | x_i, \Delta, d_i = 2) \\ &= \Phi \left[ \frac{\frac{1}{2} [E(p_2) - \alpha_{i12}] q_{i2}^* + \alpha_{01} - \alpha_{02} - \frac{1}{2} \frac{[E(p_1) - \alpha_{i11}]^2}{\left[ \frac{E(p_2) - \alpha_{i12} - \alpha_{22} q_{i2}^*}{\text{Var}(p_2) q_{i2}^*} \right] \text{Var}(p_1) + \alpha_{21}}}{\sqrt{\sigma_1^2 + \sigma_2^2}} \right] \\ &\quad * \phi \left( \frac{C_i - \alpha_{02} - \alpha_{i12} q_{i2}^* - \frac{\alpha_{22}}{2} (q_{i2}^*)^2}{\sqrt{\sigma_2^2}} \right). \end{aligned} \quad (12)$$

Combining all these results, the likelihood function for the data can be written as

$$L = \prod_{i=1}^N [\Pr(d_i = 1, C_i | x_i, \Delta)]^{1(d_i=1)} * [\Pr(d_i = 2, C_i | x_i, \Delta)]^{1(d_i=2)} \quad (13)$$

where  $N = N_1 + N_2$  and  $N_1$  and  $N_2$  are defined above. Using the data on individual hog farmers' marketing arrangement choices, production level choices, production costs, and socioeconomic characteristics, we estimate the parameter vector  $\Delta$  using maximum likelihood estimator. The  $E(p^d)$  and  $Var(p^d)$  used in estimation are computed from the sample data. After estimation, the risk aversion parameter  $\gamma_i$  and the unobserved cost component can be recovered for each farmer based on the following equations

$$\hat{\gamma}_i = \frac{E(p_d) - x_i \hat{\phi}_d - \hat{\alpha}_{2d} q_{id}^*}{Var(p_d) q_{id}^*} \quad (14)$$

and

$$\hat{\varepsilon}_{id} = C_i - \hat{\alpha}_{0d} - \hat{\alpha}_{i1d} q_{id}^* - \frac{\hat{\alpha}_{2d}}{2} (q_{id}^*)^2. \quad (15)$$

## 4 ARMS Data

Data used in this paper are obtained from the *Agricultural Resource Management Survey Phase III, Hogs Production Practices and Costs and Returns Report, Version 4, for 2004*<sup>5</sup> (hereafter, ARMS III V4, 2004). ARMS Phase III data are collected at the farm level to obtain information about farm financial statements, production practices and farm operator's household characteristics. Commodity specific information is collected on a rotating basis. Special hogs survey is done every six years: 1992, 1998, and 2004. The data from different years do not form a panel, rather they represent independent cross-sections. ARMS III V4, 2004 is a series of interviews with 1,414 farm operators from 19 states.<sup>6</sup> Furthermore, the ARMS data are nationally representative and each observation in the ARMS survey has a different weight, or expansion factor. The weights reflect each observation's probability of selection and

<sup>5</sup>This survey has been done by USDA's Economic Research Service (ERS) and National Agricultural Statistics Service (NASS) since 1975. More information and survey questionnaires can be found at: <http://www.ers.usda.gov/data/arms/globaldocumentation.htm>.

<sup>6</sup>These states are AR, CO, GA, IL, IN, IA, KS, KY, MI, MN, MO, NE, NC, OH, OK, PA, SD, VA, and WY.

can be used to prepare population estimates from the survey results. These weights are designed to expand certain variables such that they match the total industry numbers. For example, in the hogs survey case, these expansion factors are calculated to correctly expand the inventory of all hogs and pigs on December 31, 2004 to match the number reported by NASS. Using these weights we expand the number of market hogs sold or removed in ARMS 2004 to obtain the population estimate of 82,012,081.<sup>7</sup>

The survey consists of all types of hogs sold/marketed/removed during 2004. Since our major concern is with the market hogs, defined as hogs sold directly for slaughter, we delete the farmers who are not selling market hogs. This reduces the sample size to 906. Market hog transactions are captured in three different channels: cash/spot market sales, marketing contracts, and production contracts. Among 906 farmers who sell market hogs, a great majority use only one channel: 532 farmers use cash sales, 328 production contracts, 21 marketing contracts, 20 farmers use the combination of marketing contracts and cash sale, 5 farmers use production contracts and cash sales, and none of them use all three channels at the same time. Since very few farmers use marketing contracts and there are many similarities between marketing contracts and cash sales, we combine them into one category, thereafter, referred to as the cash-marketing channel.<sup>8</sup>

In Section P of the survey, the farm operators are asked to report the number of heads of market hogs sold on an open market or under a marketing contract and the total dollar amount received for these sales. Using these responses, we construct the quantities ( $q^1$ ) and average prices ( $p^1$ ) of market hogs sold through the cash-marketing channel. In the same section the farmers are asked to report the number of heads of market hogs removed under the production contracts. However, the final per unit fee received under production contracts was reported in Section D, where the survey uses a different way of classifying hogs. Instead of market hogs, the survey uses commodity codes for the various types of hogs. We use *farrow to finish* (807), *grower to finish* (808), and *finisher* (809) since all these contracts lead to the production of

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<sup>7</sup>This number can be compared to the estimates from several other sources. The number of market hogs sold in 19 states in 2004 reported in National Pork Board Checkoff system is 91,537,136, the number of hogs sold in the Mandatory Price Report (MPR) is 92,554,641, and the number of hog slaughtered reported by NASS is 103,573,000.

<sup>8</sup>Relatively small representation of marketing contracts does not seem to be in line with other publicly available sources of market hogs transactions data such as Mandatory Price Reporting (MPR). Personal communication with ERS and NASS personnel revealed that this phenomenon is the result of the fact that ARMS targets only farmers whereas marketing contracts are largely used by integrators (not included in the survey) who contract the production of live hogs with farmers but use marketing contracts to sell live hogs to packers.

market hogs.

To estimate the model, we need to obtain a measure of cost for each farmer. Finding micro level economic cost data is frequently a daunting task for researchers. Fortunately, ARMS survey asks farmers to report both the monetary cost and the opportunity costs of their enterprises. To compute the costs for farmers using the cash-marketing contract arrangement we use four components<sup>9</sup>: (a) cost of animals (from sections O and P of the survey), which equals the market value of the nursery pigs born to the existing breeding stock during the year, plus the cost of buying additional nursery pigs, feeder pigs and the breeding stock (gilts, sows and boars), minus the revenue received by selling nursery pigs, feeder pigs, and some of the breeding stock; (b) the cost of feed (from section Q), which equals the dollar amount the farmer spends on buying feed as well as the market value of the homegrown feed, if any was used to feed the animals; (c) the cost of labor (from section G), which equals the total amount of wages paid to paid workers plus the market value of the unpaid labor provided by the farm operator and family members;<sup>10</sup> (d) the opportunity cost of land, which is computed as the rental value of the land devoted to hog production.<sup>11</sup>

To compute the cost measure for farmers using production contracts, we only use the labor cost and the opportunity cost for land. As explained in Section 2, the division of responsibilities for providing production inputs between the contract parties is such that the contractor provides both young animals and feed, and the agent provides land, facilities and labor. Notice that the constructed cost measure does not represent the total cost of hog production under two scenarios but rather only variable cost.<sup>12</sup> The opportunity cost of capital and the physical depreciation of fixed assets are not included. The reason for this is that the quality of data regarding these categories is not very good and the comparable numbers for two channels would be difficult to assemble.

Finally, we also extract a number of variables describing farmers' socio-economic characteristics. After deletion of several outliers and accounting for

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<sup>9</sup>These four cost components are selected from a list of costs that are used by USDA to compute commodity costs and returns and are recommended by the American Agricultural Economics Association Task Force on Commodity Costs and Returns. More information can be found at <http://www.ers.usda.gov/data/CostsAndReturns/methods.htm>.

<sup>10</sup>To compute the cost of unpaid family labor we use \$10 an hour as this is the average hourly wage paid to the paid farm workers.

<sup>11</sup>Section S of the survey provides information on the number of acres devoted to hog production and state average rental rates for farm land in 2004 are obtained from USDA.

<sup>12</sup>This does not affect our analysis as the fixed costs drop out of the first order condition of farmers' maximization problem.

missing observations, we ended up with 599 observations. Among these 599 farmers, 351 farmers use the cash-marketing arrangements and 248 farmers use production contracts. The variable names, descriptions, and summary statistics are reported in Table 1. Two important features of the data set stand out. First, farmers who use cash-marketing arrangements are smaller and on average sell 3,459 hogs per year. Contract producers are larger and on average produce 9,085 hogs per year. Second, the average price recorded in the cash-marketing arrangement is \$119.97 per hog, while the average grow-out fee in production contracts is only about \$11.65 per hog. This large spread reflects the differences in provision of inputs between two different types of marketing arrangements and naturally leads to similar differences in production costs between the two alternative marketing arrangements. As we can infer from Table 1, on average, the cost for producing one market hog in the cash-marketing channel is about \$94 and the cost of growing one market hog in production contract is about \$2. In turn, this implies that a cash-marketing farmer makes a profit of \$26 per hog and a contract farmer makes a profit of \$9 a hog.<sup>13</sup> Given the fact that two types of farmers operate in the same geographical markets, to prevent the exodus of farmers from the low profit channel to the high profit channel, in equilibrium the profits are expected to be welfare equivalent. The observed difference in monetary profits between two channels are naturally explained as the risk premium that contract farmers are willing to pay to replace a highly uncertain stream of returns from the spot selling with a reasonably secure stream of returns from contracting.

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<sup>13</sup>USDA estimates that the profit on hog production per hundredweight gain is \$8.03 in 2004, see <http://www.ers.usda.gov/Data/CostsAndReturns/data/current/C-Hogs.xls>. As market hogs usually weigh around 250 pounds, our profit measure is pretty close to the USDA estimate.

**Table 1: Summary Statistics<sup>14</sup>**

Variable	Mean	Std. Dev.	Mean	Std. Dev.
	Cash		Production Contract	
farmtype	0.6125	0.4879	0.6411	0.4806
farmsize	813.7464	1155.5830	519.1492	712.4719
east	0.0855	0.2800	0.3669	0.4829
cornbelt	0.8889	0.3147	0.5202	0.5006
age	51.4501	10.8844	49.9395	10.3822
male	0.9858	0.1187	0.9758	0.1540
educ	0.4900	0.5006	0.5323	0.5000
nfamily	3.4046	1.8288	3.2702	1.4880
nfasset	12.2619*10 <sup>4</sup>	21.6240*10 <sup>4</sup>	15.8661*10 <sup>4</sup>	26.9109*10 <sup>4</sup>
cost	32.5474*10 <sup>4</sup>	65.0787*10 <sup>4</sup>	1.9972*10 <sup>4</sup>	1.5834*10 <sup>4</sup>
<i>q</i>	34.5878*10 <sup>2</sup>	76.7679*10 <sup>2</sup>	90.8460*10 <sup>2</sup>	94.3319*10 <sup>2</sup>
<i>p</i>	119.9668	19.5879	11.6510	2.5896

## 5 Estimation Results

The MLE estimation results for the cost functions are summarized in Table 2. To account for possible systematic differences across farmers, we choose farm type, farm size, region (east and cornbelt), age, sex (male), education, family size (number of family members), and wealth (value of non-farm assets). Several estimation results are worth emphasizing.

First, the farm size variable is significant and has a negative impact on the cost, i.e. the more land the farmer has, the lower the cost of producing hogs. This is true for both enterprises, independent (cash-marketing) and production contracts. Aside from the land occupied by the production facilities (which is not that much), land is used for the production of feed and for manure disposal. The latter is becoming an increasingly difficult problem to solve, especially for farmers in areas with concentrated animal production. So, obviously farmers with more land will have lower cost of both producing their own feed and disposing of animal waste. The farm type variable, on the other hand, is not significant. It appears that whether the hog operation is the main business on

<sup>14</sup>Sample size: 351 for cash farmers and 248 for production contract farmers. farmtype: 1 if hog operation is the main business. farmsize: the acreage of the farm. east: 1 if in NC, VA and GA. cornbelt: 1 if in KY, OH, IN, MI, IA, WI, MN, SD, IL, MO, KS, NE. age: age of the farm operator. male: 1 if farm operator is male. educ: 1 if at least has some college. nfamily: number of family members. nfasset: value of non-farm assets. cost: total cost of production. *q*: number of market hogs produced. *p*: price per hog/fee per hog received

the farm or not, does not significantly influence the cost of production.

**Table 2: Production Cost Function Estimation Results**

Variable	Estimate	t-stat	Estimate	t-stat
	Cash		Production Contract	
cons	53.1785	0.91	0.5437	1.10
farmtype	8.8547	1.28	-0.0019	-0.01
farmsize	-0.0019	-2.39	-0.0002	-3.24
east	36.9021	1.87	-0.2314	-1.98
cornbelt	0.8828	0.05	0.7301	4.80
age	-0.4954	-4.33	0.0219	5.80
male	4.0451	0.07	-0.3666	-0.94
educ	-6.7673	-2.71	-0.5240	-6.25
nfamily	4.5957	13.41	-0.0590	-2.49
nfasset	$0.1275 \cdot 10^{-4}$	2.70	$0.9988 \cdot 10^{-7}$	0.60
$\alpha_2$	$0.7392 \cdot 10^{-4}$	9.01	$0.4420 \cdot 10^{-4}$	11.64
$\alpha_0$	$313.8788 \cdot 10^2$	2.62	$79.1690 \cdot 10^2$	5.01
$\sigma^2$	$3.6231 \cdot 10^{10}$	55.69	$1.2307 \cdot 10^8$	15.31
Log Likelihood			-7469.9	

Second, geographic location of the farm matters for cost-efficiency. Cash-marketing hog farmers in the East (North Carolina, Virginia, Georgia), all of which have limited tradition in hog farming, have higher cost of producing hogs relative to farmers in the other regions. Of course, the opposite is true when it comes to contract producers. North Carolina being the cradle of production contracts have clearly lower cost of contract production than other regions. The sign of the other regional variable (cornbelt) is in line with the above results.

Third, farmers' socioeconomic characteristics impact the cost of production in different ways. Sex of the operator does not matter for cost-efficiency, a perfectly reasonable result. On the other hand, education coefficient is negative and significant, indicating that some college education reduces the cost relative to no college education. Age of the farm operator is also significant but, interestingly enough, affects the cash-marketing farmers differently than production contract farmers. An older cash-marketing farmer incurs lower cost of production, whereas an older contract farmer incurs higher cost. This may be due to the fact that producing hogs for the spot market is a traditional way of doing business and older farmers are more familiar with the process. On the other hand, older farmers may have difficulty understanding sometimes

complicated contract provisions and following instructions regarding new production practices. The family size variables have the opposite signs from the age variables. The more family members the operator's household has, the higher the cost of producing hogs in the cash-marketing enterprise and the lower the cost in the contract enterprise. On the traditional cash-marketing side, this result could be indicative of inefficient family labor management or simply a fact of creative accounting in the sense that everybody's labor has to be charged to some farm enterprise regardless of whether it is really productively needed or not. On the contract side, it is really hard to envision why would larger families be more cost-effective than smaller ones. Finally, farmers with larger non-farm assets tend to have larger production cost (in the contract scenario this variable is insignificant). This result indicates that as more resources, and consequently more income, is related to non-farming activities, the costs of farming activities increase, as less attention is devoted to what used to be the core business.

Fourth, it is also worth mentioning that the slope of the marginal cost functions  $\alpha_2$  are both positive and significant as required by the economic theory.

**Table 3: Distribution of Risk Aversion Parameters**

Statistics	Values	
	Cash	Production Contract
10% percentile	$1.86*10^{-5}$	$7.06*10^{-5}$
25% percentile	$4.96*10^{-5}$	$1.26*10^{-4}$
50% percentile	$1.45*10^{-4}$	$2.42*10^{-4}$
75% percentile	$4.47*10^{-4}$	$5.83*10^{-4}$
90% percentile	$0.16*10^{-2}$	$0.17*10^{-2}$
mean	$5.24*10^{-4}$	$5.72*10^{-4}$
standard deviation	$9.81*10^{-4}$	$9.80*10^{-4}$

With the estimated cost functions and the sample estimates of  $E(p_d)$  and  $Var(p_d)$ , we can now use (14) to recover the risk aversion parameter for each individual farmer. The summary statistics are presented in Table 3. The absolute magnitudes of the risk aversion parameters are not informative as they depend on the revenue units. As clearly seen from (14), a large magnitude of  $q_{id}^*$  leads to a small magnitude for  $\gamma_i$ , everything else being equal. On the other hand, the comparison of the risk aversion parameters between channels do reveal which farmers are more risk averse. It is clear that cash-marketing farmers are less risk averse than contract farmers as their risk aversion parameters are smaller at different percentiles of the distribution. The obtained

results are consistent with the economic intuition that those farmers who are more risk averse self select themselves into less risky projects.<sup>15</sup> In production contracts, significant amount of risk is transferred from a farmer to an integrator or a packer, as payment mechanisms typically insulate contract operators from market price volatilities. The companies that offer contracts are typically quite large and sometimes publicly owned and are therefore better positioned to bear risk than small farmers. On the other hand, those farmers who use the cash-marketing arrangement are exposed to substantially more risk than their production contract counterparts and it is reasonable to expect that they correctly self-selected themselves into projects whose riskiness is in line with their risk tolerance.

## 6 Welfare Simulation and Measurement

In this section we use the estimates of farmers' utility and cost functions from Section 5 to simulate how changes in the availability of alternative marketing arrangements affect the farmers' welfare. Our counterfactual experiment consists of banning the production contracts in South Dakota and hence those farmers who originally used production contracts must now use the cash-marketing arrangements or leave the industry. South Dakota is a state where only about 200,000 hogs are produced using production contracts every year, so we assume that the proposed regulation is not going to affect the live hog prices coming through either one of the two channels, neither will it have any impact on the downstream market for pork.

The experiment is carried out as follows. First, with the estimated model primitives and the observed production quantity, we can use equation (2) to compute the certainty equivalent profits for those contract farmers affected by the proposed regulation as

$$W_i(R_{i2}^*, q_{i2}^*) = E(p_2)q_{i2}^* - \frac{\gamma_i}{2}Var(p_2)(q_{i2}^*)^2 - \alpha_{02} - \alpha_{i12}q_{i2}^* - \frac{\alpha_{22}}{2}(q_{i2}^*)^2 - \varepsilon_{i2}, \quad i = 1, \dots, N_2 \quad (16)$$

where the subscript 2 denotes the production contract arrangement and  $N_2$  denotes the number of farmers in South Dakota who choose production contracts.

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<sup>15</sup>The obtained results are consistent with the earlier channel contract behavior literature. For example, Pennings and Wansink (2004) also found that risk attitudes varied widely among Dutch hog producers. For the importance of risk aversion in contract choice see also Pennings and Smidts (2000) cited earlier.

Second, we use the first order condition (14) to predict how many hogs each farmer who originally produced hogs under contract will now choose to produce under the cash-marketing arrangement as

$$q_i^{new} = \frac{E(p_1) - \alpha_{i11}}{\gamma_i Var(p_1) + \alpha_{21}} \quad (17)$$

where subscript 1 denotes the cash-marketing arrangement.

Finally, we calculate the new certainty equivalent for these farmers affected by the regulation using (2) and the newly predicted hog production volume from the second step as

$$W_i^{new}(R_i^{new}, q_i^{new}) = E(p_1) q_i^{new} - \frac{\gamma_i}{2} Var(p_1) (q_i^{new})^2 - \alpha_{01} - \alpha_{i11} q_i^{new} - \frac{\alpha_{21}}{2} (q_i^{new})^2 - \varepsilon_i^{new}, \quad i = 1, \dots, N_2. \quad (18)$$

$\varepsilon_i^{new}$  is unobserved, but from (6), we know that for these production farmers, the following must hold

$$\varepsilon_i^{new} > \varepsilon_{i2} - \left( E(p_2) q_{i2}^* - \frac{\gamma_i}{2} Var(p_2) (q_{i2}^*)^2 - \alpha_{02} - \alpha_{i12} q_{i2}^* - \frac{\alpha_{22}}{2} (q_{i2}^*)^2 \right) + \left( E(p_1) q_{i1}^* - \frac{\gamma_i}{2} Var(p_1) (q_{i1}^*)^2 - \alpha_{01} - \alpha_{i11} q_{i1}^* - \frac{\alpha_{21}}{2} (q_{i1}^*)^2 \right). \quad (19)$$

Since  $\varepsilon_i^{new}$  is assumed to be a normally distributed random variable, a reasonable proxy for  $\varepsilon_i^{new}$  is the mean of the truncated normal distribution with the truncation described in (19).<sup>16</sup> The difference between the two certainty equivalent measures can be taken as the welfare effect associated with the proposed regulation. In fact it is a measure of *compensating variation*, which is defined as the amount of money which when taken away from a farmer after the regulation, leaves him just as well off as before. For a welfare gain it is the maximum amount that the farmer would be willing to pay for the regulation, for a welfare loss it is the negative of the minimum amount that the farmer would require as compensation for the imposed regulation. A positive *CV* means the farmer benefits from the regulation, a negative *CV* means the farmer loses with regulation.

The results are summarized in Table 4. As we can see, there is a significant drop in production of contract farmers that are the target of the proposed regulation. The regulation forces them to switch to the cash-marketing arrangement which is inherently more risky than the production contract. Since they are risk averse, they need to reduce their risk exposure and naturally they reduce their supplies of market hogs significantly. Consequently, they suffer welfare losses. An average contract farmer's welfare loss amounts to \$34,898 per year with a standard deviation of \$6,188 per year.

<sup>16</sup>We thank a referee for making this suggestion.

**Table 4: Welfare Effects of Banning the Production Contracts in South Dakota**

Indicator	Value	Sample Size
Hogs produced in SD by cash farmers (before)	78,060	17
Hogs produced in SD by production contracts (before)	24,239	5
Reduction in hogs produced in SD (after)	21,654	5
Mean of CV (in \$) for Production Farmers	-34,898.46	5
Std. Dev. of CV (in \$) for Production Farmers	6,188.24	5

## 7 Conclusion

The objective of this paper was to estimate the farmers' side welfare effects of a hypothetical regulatory scenario that would partially ban production contracts in the hog industry. Our results show that farmers who self-select themselves into production contracts are generally more risk averse than farmers who decided to market their hogs via the cash (spot) market or marketing contracts. By eliminating production contracts some farmers who originally chose this marketing arrangement would be forced to switch over to the spot market or marketing contracts. Since this marketing arrangements carry higher risk, in order to reduce their risk exposure, risk-averse farmers respond by reducing output.

The main contribution of this paper is that it illuminates one of the most important consequences of potential regulation of alternative marketing arrangements in agriculture. When contemplating various policy proposals for the regulation of contracts, policy makers frequently ignore the fact that farmers are risk averse. In fact, risk aversion is necessary to explain why farmers adopt various types of alternative marketing arrangements to begin with. As we showed in Section 4, risk aversion is also necessary to explain the apparent differences in monetary payoffs across different marketing channels in the same sector and the same geographical markets. Realizing that a regulatory proposal that would force farmers to adopt the marketing channel that is not in line with their risk attitudes can cause serious welfare losses could profoundly alter the current debate in favor of more subtle, scientifically based proposals.

Finally, the obtained results need to be interpreted cautiously as they are reflective of the "small economy" case where all general equilibrium price adjustments are ignored. If one would want to extent this analysis towards regulatory proposals with more industry coverage, the analysis would have to include general equilibrium adjustments in terms of the packer side factor demands for live hogs as well as the downstream demand for pork and pork cuts.

Such exercises tend to be extremely complicated with models based on micro level data (plant and farm household), and are usually done with aggregated industry level data instead.<sup>17</sup>

In addition, one also has to look at the aggregate welfare gains or losses of all players potentially impacted by the regulation. Even if the results show that contract farmers may lose, cash farmers could gain. This still does not mean that the proposed regulation would benefit the entire industry as in all likelihood the hog integrators and packers are bound to lose as their procurement practices will be disturbed by such regulation. The welfare analysis could be further complicated by the fact that the price of pork is likely to go up causing welfare losses for consumers.

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<sup>17</sup>For the results of such a study see Vukina et al. (2007, Chapter 6).

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